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(72) Qiu, Xing Xing, CA
(72) Shih, Yi-Chi, US
(71) Qiu, Xing Xing, CA
(71) Shih, Yi-Chi, US

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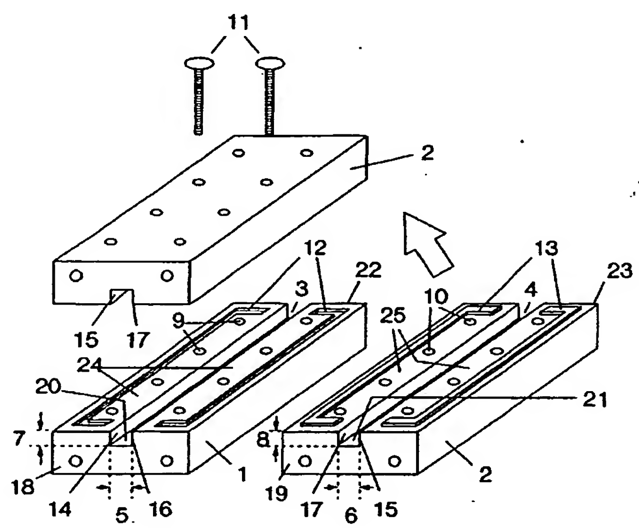
(54) **METHODES DE FABRICATION DE COMPOSANTES HYPERFREQUENCES LEGERES ET ECONOMIQUES POUR UTILISATION A HAUTES FREQUENCES**

(54) **METHODS OF MANUFACTURING LIGHTWEIGHT AND LOW COST MICROWAVE COMPONENTS FOR HIGH FREQUENCY OPERATION**



(57) Méthodes de fabrication de guides d'ondes à ondes millimétriques et de composantes de guides d'ondes légères et économiques pour utilisation à de très hautes fréquences. Dans une application, des boîtiers thermoplastiques moulés sont utilisés pour la fabrication de guides d'onde. Une couche de métal est appliquée par dépôt autocatalytique sur chacune des parois intérieures des boîtiers des guides d'ondes et sur les surfaces d'interconnexion. Après la métallisation, un nettoyage est effectué pour minimiser la quantité de produits chimiques laissés dans et sur la surface des pellicules d'argent en vue d'en accroître la stabilité. Les boîtiers

(57) Methods for the fabrication of light weight and low cost millimeter-wave waveguides and waveguide components for very high frequency operation are disclosed. In one embodiment, molded thermoplastic waveguide housings are used in the fabrication. A layer of metal is plated by electroless deposition on each of the inner walls of the waveguide housings and surfaces for interconnection. After the plating, a cleaning step is carried out to minimize the amount of chemicals left in and on the surface of the Ag films so as to improve lifetime stability. The waveguide housings are finally joined together to form the final microwave components.

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des guides d'ondes sont finalement joints pour former les composantes hyperfréquences finales. Dans une autre application, des boîtiers de guides d'ondes moulés constitués de matériaux thermoplastiques conducteurs sont utilisés. Une couche de métal est appliquée par électrodéposition sur chacune des parois des boîtiers des guides d'ondes et sur les surfaces d'interconnexion. Les boîtiers des guides d'ondes sont ensuite joints pour former les composantes hyperfréquences finales.

In another embodiment, molded waveguide housings from conductive thermoplastic materials are used in the fabrication. A layer of metal is then plated by electrodeposition on each of the inner walls of the waveguide housings and surfaces for interconnection. The waveguide housings are finally joined together to form the final microwave components.

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METHODS OF MANUFACTURING LIGHTWEIGHT AND LOW COST MICROWAVE COMPONENTS FOR HIGH FREQUENCY OPERATION

ABSTRACT OF DISCLOSURE

Methods for the fabrication of light weight and low cost millimeter-wave waveguides and waveguide components for very high frequency operation are disclosed. In one embodiment, molded thermoplastic waveguide housings are used in the fabrication. A layer of metal is plated by electroless deposition on each of the inner walls of the waveguide housings and surfaces for interconnection. After the plating, a cleaning step is carried out to minimize the amount of chemicals left in and on the surface of the Ag films so as to improve lifetime stability. The waveguide housings are finally joined together to form the final microwave components. In another embodiment, molded waveguide housings from conductive thermoplastic materials are used in the fabrication. A layer of metal is then plated by electrodeposition on each of the inner walls of the waveguide housings and surfaces for interconnection. The waveguide housings are finally joined together to form the final microwave components.

BACKGROUND OF THE INVENTION

1. Field of the invention

The invention relates generally to methods for fabrication of microwave waveguides and waveguide components. More specifically, the invention relates to fabrication of waveguides and components for very high frequency operation.

2. Description of the prior art

Waveguides are important elements in many microwave systems and are used to guide microwaves in a high frequency system from a given location, hereinafter called a source, to other locations, hereinafter called loads. The main factors which affect the design of microwave waveguides and waveguide components include: wavelength of operation, attenuation or loss, precise inner dimensions and alignment of the elements to the housing. At high frequencies, the conductivity of the substances used to construct the waveguides must be low in order to minimize the loss. Conventional waveguides are manufactured from formed metal sheets of copper alloy, silver-lined copper alloy and silver alloy. The thicknesses of the metal sheets used is about 0.5-2 mm. At the two ends of a waveguide, brass flanges are affixed for connecting purposes. Although it is possible to reduce microwave loss, the conventional brass waveguides have several drawbacks. The drawbacks of the brass waveguides are: (1) they are relatively expensive to manufacture, (2) they are relatively heavy, (3) they are rigid and relatively difficult to reproduce.

When waveguides or waveguide components are used in modern electronic systems, it is highly desirable to reduce

the waveguide weight, to reduce the fabrication cost and to improve reproducibility. While there are methods to overcome the above problems, no method to produce stable and light weight waveguides that operate at very high frequencies is known. For example, a waveguide structure is disclosed in US Patent No. 5,398,010 to D.O. Klebe. In Klebe's method, a housing is first formed by bonding molded thermoplastic elements using epoxy adhesive. A layer of copper is then deposited by electroless plating on the surfaces of the housing to form the waveguide. Although Klebe's method has been utilized with certain success in manufacturing waveguides, there are drawbacks to his method. Firstly, the assembling of the thermoplastic elements into a waveguide housing is not only tedious but also requires curing of the epoxy adhesive, which is time consuming. Secondly, due to the nature of the bonding of the thermoplastic elements prior to the electroless copper plating, some detrimental effects may occur in Klebe's waveguides. When the amount of epoxy adhesive is insufficient in a local region, a gap may form between adjacent elements. When this occurs, traces of chemicals in the solution for electroless copper deposition may be trapped in gaps between adjacent elements. The trapped chemicals may degrade the plated copper films on the thermoplastic and affect their lifetime stability. When excessive epoxy adhesive is applied in a local region and the thermoplastic elements are squeezed during the assembling process, some of the epoxy may be forced into the waveguide cavity, leading to deformation of the cross section of the otherwise rectangular waveguide housing. To overcome this problem, Klebe's invention requires an additional step of time consuming machining of the housings prior to the metal deposition. This machining of the thermoplastic waveguide housings is undesirable because it may cause environmental contamina-

tion. Thirdly, Klebe's method is not suitable for providing the predetermined curvature between the elements joined by the epoxy adhesive. The predetermined curvature is important in obtaining continuous metal deposition by electroless deposition or even electrodeposition. Fourthly, the electrical resistivity of the copper layer, especially at corner regions, is often not low enough to minimize the loss of microwaves when operation frequencies are very high. Yet another drawback of Klebe's method is that it is difficult to incorporate elements inside the waveguides for the conditioning of the microwaves. For instance, to form a filter waveguide, it is necessary to install a patterned metal foil within the waveguide housing. The electrical properties of the patterned metal foil are important for the conditioning of microwaves. The patterned metal foil may be attacked by the solution used for the copper electroless deposition process. Hence, the structures and processes described by Klebe cannot produce high quality microwave waveguide components for operation at frequencies exceeding 20 GHz.

From the above comments, it is clear that an improved method for the manufacturing of light weight microwave waveguides and components that does not require elements be bonded using epoxy adhesive and does not require subsequent curing and final machining is needed. The waveguide components which are manufactured according to this invention are especially suitable for operation at frequencies higher than 20 GHz.

SUMMARY OF THE INVENTION

The present invention provides a method to manufacture light weight and low cost microwave waveguides and waveguide components which can operate at frequencies greater than 20 GHz with excellent lifetime stability, without the need of bonding of the elements using epoxy adhesive, curing and subsequent machining. This method involves the deposition of a layer of high quality metal on molded thermoplastic members to form conducting waveguide members. The conducting members are then assembled to form a waveguide. Because with this method, joining of the thermoplastic elements by epoxy to form thermoplastic members prior to the metal deposition is not required, it is thus clear that the drawbacks in Klebe's method are eliminated. Included in this invention is a method for manufacturing microwave waveguides by silver plating comprising the steps of:

-- forming a first component and a second component by the molding of thermoplastic materials, said first component containing at least one surface for connecting to sources, at least one connecting surface for connecting to loads, at least one cavity and at least one female slot for alignment and assembly, said second component containing at least one connecting surface for connecting to sources, at least one surface for connecting to loads, at least one cavity and at least one male slot for alignment and assembly, each of the cavities in said first component coinciding with a cavity in said second component and each female slot in said first component coinciding with a male slot in said second component,

-- coating at least one layer of metals on said connecting surface and inner walls of cavities of said first component and on said connecting surface and inner walls of cavities of said second component,

-- rinsing thoroughly said first component and said second component with water,

-- drying thoroughly said first component and said second component in air and then heat treating said first component and said second component in vacuum or in an inert atmosphere,

-- assembling said first component and said second component to form a waveguide structure.

In addition, included in this invention is a method for manufacturing light weight waveguide components containing elements for the conditioning of microwaves comprising the steps of:

-- forming a first component and a second component by molding of thermoplastic materials, said first component containing at least one surface for connecting to sources, at least one connecting surface for connecting to sinks, at least one recess slot to accommodate said elements for the conditioning of microwaves, at least one cavity and at least one female slot for alignment and assembly, said second component containing at least one connecting surface for connecting to sources, at least one surface for connecting to loads, at least one recess slot to accommodate said elements for conditioning of microwaves, at least one cavity and at least one male slot for alignment and assembly. Each of the recess slots in said first component coinciding with one recess slot in said second component, each of cavities in said first component coinciding with a

cavity in said second component and each female slot in said first component coinciding with a male slot in said second component,

-- coating at least one layer of metals on said connecting surface and inner walls of cavities of said first component and on said connecting surface and inner walls of cavities of said second component,

-- rinsing thoroughly said first component and said second component with water,

-- drying thoroughly said first component and said second component in air and then heat treating said first component and said second component in vacuum or in an inert atmosphere,

-- positioning said elements for the conditioning of microwaves in recess slots,

-- assembling said first component and said second component with said elements to form a waveguide component structure for the conditioning of microwaves.

In another embodiment, molded waveguide housings from conductive thermoplastic materials are used in the fabrication. Since the waveguide housings are electrically conductive, a layer of metal may be plated by electrodeposition rather than electroless deposition on each of the inner walls of the waveguide housings and surfaces for interconnection. The waveguide housings are finally joined together to form the final microwave components.

By depositing metal layers on preformed thermoplastic components, the amount of trapped chemicals in the deposited metal layers can be minimized. Furthermore, with the use of silver coating, the electrical resistivity may be substantially reduced as compared to prior art methods.

Finally, with the provisions of the recess slots to accommodate the elements, light weight and low cost waveguide component structures for microwave conditioning may be manufactured.

One object of the present invention is to provide a method to fabricate light weight and low cost microwave waveguides which can operate at frequencies exceeding 20 GHz.

Another object of the present invention is to provide a method to fabricate light weight and low cost microwave waveguides with good lifetime stability.

Yet another object of the present invention is to provide a method to fabricate light weight microwave waveguide components containing elements for the conditioning of microwaves.

Still another object of the present invention is to provide a method to fabricate microwave waveguides or waveguide components using molded conductive thermoplastics.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of two plastic members fabricated to form a waveguide.

Fig. 2 is a schematic view of a part of a molded plastic member showing the predetermined radius of curvature between two adjacent surfaces of the cavity.

Fig. 3 is a schematic view of a two plastic members and a metal foil element fabricated and assembled in such a way as to form a waveguide filter component.

Fig. 4 is a schematic view of a metal foil element fabricated for the conditioning of microwaves.

Fig. 5 is a schematic view of two plastic members fabricated for the microwave circulator component.

While the invention will be described in conjunction with the illustrated embodiments, it should be understood that it is not intended to limit the invention to such embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, similar features have been given similar reference numerals. In the following description, a structure for the propagating of microwaves is called microwave waveguide whereas a structure which alters the properties of microwaves is called microwave waveguide component.

According to this invention, plastic members (1,2) as shown in Fig. 1 are fabricated from thermoplastic materials by one-step molding. Such thermoplastic materials may be fiber-filled polyimides (with 30% glass fibers, for example), which are available commercially, for instance form RTP Company, Winona, MN, USA. Member (1) has at least one channel slot (3) and member (2) has at least one channel slot (4). Both width (5,6) and height (7,8) of the slots in members (1,2) are selected so that when the two members are assembled to form a waveguide or waveguide component, a channel suitable for propagation of microwaves at desired frequencies will be obtained. The channel in the assembled waveguide or waveguide component has a width of (5) or (6) and a height of 2 times of (7) or (8). In order to assemble members (1,2) to form a waveguide or waveguide component, holes (9,10) are formed in the two members to accommodate screws (11). For operation at frequencies greater than 20 GHz, the alignment of the two members is important. To ensure accurate alignment, at least one female slot (12) is formed in member (1) and at least one male slot (13) is formed in member (2). The positions of the female slots (12) relative to channel slot (3) are the same as those for the male slots (13) relative to the

channel slot (4). Hence, when members (1,2) are assembled to form a waveguide or waveguide component, side wall (14) in member (1) will be aligned precisely with side wall (15) in member (2), whereas side wall (16) in member (1) will be aligned precisely with side wall (17) in member (2). After the molding of the two members and prior to the assembly, a layer of metal such as Ag is deposited by electroless deposition on all the surfaces of each member. Coverage of surfaces (14,16,18,20,22,24) in member (1) is particularly important. This is because surfaces (14,16,20) define the channel of the waveguide or waveguide component whereas surfaces (18,22,24) ensure electrical continuity between the two members and the components of the source and the load. It is noted that surface (22) corresponds to the surface (18). Both surface (22) and surface (18) are for electrical continuity for connecting purposes. Similarly, the coverage of surfaces (15,17,19,21,23,25) in member (2) is important. Surfaces (15,17,21) define the channel of the waveguide or waveguide component whereas surfaces (19,23,25) ensure the electrical continuity between the two members and the components of the source and load. Surface (23) corresponds to the surface (19) and both are for electrical continuity for connecting purposes.

The advantages of the method according to this invention for the fabrication of waveguides and waveguide components are thus obvious. Since these plastic members (1,2) are formed by one-step molding, there are no gaps or excess materials between the adjacent plastic elements, for example between surface (14) and surface (20) of member (1) as shown in Fig. 1. In the prior art method disclosed in U.S. Patent No. 5,398,010 granted to D.O. Klebe, plastic elements were first formed by the molding of thermoplastic materials. The elements were then assembled by aligning

said elements and joining them using epoxy adhesive. This aligning and joining is not only time consuming but may also lead to variations in the dimensions of the final members. As stated before, Klebe's method has several other drawbacks. Due to the nature of the bonding of the thermoplastic elements prior to the electroless copper plating, some detrimental effects may occur in the waveguides produced. When the amount of epoxy adhesive is insufficient in a local region, a gap may form between adjacent elements. When this occurs, traces of chemicals in the electroless copper deposition solution may be trapped in gaps between adjacent elements. The trapped chemicals may degrade the plated copper films on the thermoplastic and affect their lifetime stability. When excessive epoxy adhesive is applied to a local region and the thermoplastic elements are squeezed during the assembling process, some of the epoxy may be forced into the waveguide cavity, leading to deformation of the cross section of the otherwise rectangular waveguide. Hence, it is clear that Klebe's method is not suitable for providing the predetermined curvature needed between the elements joined by the epoxy adhesive. The curvature is important for waveguides and waveguide components especially for high frequency operation. This is because it is important to obtain continuous metal deposition by electroless deposition or even electrodeposition. As shown in Fig. 2, a predetermined curvature in the interface region (40) between surface (14) and surface (20) may be formed during the molding. The radius (R) of curvature is selected so as to be much smaller than the height (7) or width (5) of the channel surfaces. For instance, a radius of curvature of about 20 micrometers may be used. This radius of curvature is suitable to obtain continuous metal layer coverage without disturbing the propagation of the microwaves. Hence, the

structures and processes described by Klebe are not suitable for producing high quality microwave waveguides or waveguide components for operation at frequencies exceeding 20 GHz.

The deposition of Ag by the electroless deposition method according to this invention can be carried out as follows:

In this example for the Ag deposition, two parts of solution are used. Part A of the solution is prepared as follows:

Part A:

[1] Put 425 mg of $AgNO_3$ in a beaker and add 50 CC of DI water. Stir thoroughly and then add 24 drops of 37% NH_4OH. Stir thoroughly. Do the above preparation in a dark room and avoid direct illumination of the $AgNO_3$ solution.

[2] Add 300 mg of NaOH to the solution in [1] and stir thoroughly. Do the above preparation in a dark room and avoid direct illumination of the $AgNO_3$ solution.

Part B of the solution is prepared as follows:

Part B:

[1] Put 60 mg of Sparkleen in a beaker and add 100 CC of DI water. Stir thoroughly.

[2] Put 860 mg of sorbital in a beaker. Add 30 CC DI of water and stir thoroughly. Add 3 mg of Sparkleen in the beaker and stir thoroughly.

Ag Electroless Deposition Process

The silver electroless deposition is carried out in the following manner.

[1] Place the cleaned plastic members in a plastic or glass container.

[2] Take 7 cc of the solution of Part A and pour this solution into a clean beaker. Add 8 drops of the solution of Part B into the beaker and stir for 20 seconds.

[3] Pour the mixed solution into the container containing the plastic members and stir gently for 4 minutes. A layer of Ag is deposited on the plastic members.

The above processes [2] and [3] are repeated eight times to complete the silver electroless deposition. After the deposition, the plastic members are dried either by spinning or wind blowing. Finally, the plastic members are heat treated at a temperature between 100 and 200°C for 10 minutes, preferably in an inert atmosphere such as nitrogen or argon, to improve the adhesion. Alternatively, the heat treatment may also be carried out in vacuum to minimize oxidation of the deposited metal layer. After the heat treatment, the plastic members are assembled to form the final waveguides. The above electroless deposition of silver on the plastic members may also be achieved by supplying Part A and Part B of the solution at a ratio of 7 cc to 10 cc about 30 seconds prior to allowing the solution to flow into the container for the deposition. The 30 seconds time is permitted so that the mixed solution can start to react to form silver deposits. It should be noted that the time for the reaction to start is dependent on the solution temperature. When the solution temperature is higher than room temperature, the time required for the reaction to start decreases.

Thus, in the present method, after the forming of the plastic members, a layer of silver is deposited by electroless deposition process to form the conductor. The

silver layer is deposited to a thickness of about 1-3 micrometers. Since the electrical conductivity of silver is high, the thin silver layer is sufficient to minimize the loss of microwaves at high frequency. It is thus evident that, in addition to the various advantages stated above, the time required to fabricate waveguide members using the method according to this invention is less than that required when Klebe's method is used.

To further improve the quality of waveguides or waveguide components, a second layer of metal may be deposited by electrodeposition following the first electroless deposition. The electrodeposition may be carried out by conventional methods which have been know for Ag or Cu. In this case, the thickness of the first metal layer may be as small as 0.1 micrometer. This thickness is sufficient to serve as the conducting electrode during the electrodeposition for the second metal layer. The thermoplastic polyimide materials used in the description of the above embodiments contain 30% of glass fibers. The purpose of adding glass fibers to the polyimide is to improve its mechanical properties. After the molding, the mechanical properties can be improved further by annealing at elevated temperatures (upto 650^{o}F). However, it should be noted that the surface morphology of the molded polyimide containing fibers is dependent on annealing temperature. When annealed at a temperature close to 650^{o}F, the surfaces of the molded polyimide containing the fibers are too rough for high frequency waveguides or waveguide components. It is thus preferred to keep annealing temperatures substantially below 650^{o}F.

In order to incorporate an element in a waveguide to condition microwaves (see Fig. 3), recess regions (26) are formed on surface (24) of the member (1) whereas recess

regions (27) are formed on surface (25) of member (2) during the molding. The length and width of both recess regions (26,27) are selected so that element (28) can fit into the waveguide members during assembly so as to form a waveguide component. After the deposition of the metal layer, element (28) is placed within the recess regions and assembled. For a tight fit, the depth of the recess regions is selected so as to be slightly smaller than half of the thickness of element (28). Element (28) for conditioning of the microwaves may be fabricated by etching a Cu foil to form a structure, as shown in Fig. 4, with several metal strips (29). The thickness of the Cu foil is about 50 micrometers. The width (30) and spacing (31) of the metal strips are selected to achieve the desired conditioning function for the microwaves.

The methods described above can be used to fabricate various waveguide components. Fig. 5 shows a circulator structure for operation at millimeter wave frequencies. One member (32) is molded with plastic material containing several channel regions (34,35,36). The other member (33) is also molded into a structure similar to that of member (32), except that member (32) has female slots (37) for alignment purposes and member (33) has male slots (not shown). After the molding, a layer of metal such as Ag is deposited on all the surfaces. Thickness of the metal layer is at least 1 micrometer. After the metal deposition, the two members are assembled to form a circulator component. Microwaves incident from port (38) will reach port (39) but will not reach port (40). Whereas microwaves incident from the port (39) will reach port (40) but will not reach port (38).

Prior to the metal deposition, it may be necessary to clean plastic members which have been exposed to room air

for a prolonged period of time in order to obtain films with reasonably good adhesion to the plastic members. The cleaning procedure is described below. A cleaning solution containing 60 mg Sparkleen in 200 cc of de-ionized water (hereinafter called DI water) is first prepared. The plastic members are then immersed in the cleaning solution and brushed using a cotton wool brush for 5 minutes. The cotton wool brush may be driven by a motorized mechanism to increase the efficiency. After the cleaning, the plastic members are rinsed in DI water for at least 2 minutes. After the rinsing, the plastic members are ready for the silver deposition. It should be noted that the above processing does not include a catalyst and a sensitizer. However, the inventors have observed that adhesion of silver films to the plastic members cleaned with the above-described method can be improved by adding small amounts of cleaning agents to the electroless deposition solution for the silver.

The cleaning and activation processes for the plastic members are as follows:

[1] Degrease by putting the plastic members in methyl ethyl ketone (MEK) at room temperature for 5 minutes.

[2] Rinse the plastic members in DI water at room temperature for 2 minutes

[3] Immerse the plastic members in the following multiple acting solution (MAS) at room temperature for 3-6 minutes.

2.64 g $SnCl_2$-$2H_2O$
0.66 g detergent
50 CC dimethyl formamide

[4] Rinse in DI water for 2 minutes.

[5] Immerse the plastic members in the following deglazing

solution for 2-5 minutes at room temperature.

Deglazing solution

3.5 g chromic acid (CrO_3)

30 CC H_2O

25 CC H_2SO_4

[6] Immerse the plastic members in a 50% aqueous solution of concentrated reagent ammonium hydroxide at room temperature for 4 minutes to neutralize.

[7] Rinse in DI water at 25°C for 2 minutes

[8] Immerse the plastic member in the following sensitizing solution at room temperature for 4 minutes.

2.64 g $SnCl_2$-$2H_2O$

0.66 g detergent

50 CC dimethyl formamide

[9] Rinse in DI water at room temperature for 2 minutes

[10] Immerse the plastic members in the following activating solution for 1-6 minutes at room temperature.

Activating solution

7 mg PdCl

6.67 g HF

6.67 g HCl

30 CC H_2O

[11] Rinse in DI water for 4 minutes

[12] After the final rinsing, deposit the Ag layers. Heat treat the sample at 100 °C for 10 minutes. The Ag film adheres quite well and survives the Scotch tape pull test.

The solution used in this example again includes two parts. Part A of the solution is prepared as follows:

Part A:

[1] Put 425 mg of $AgNO_3$ in a beaker and add 50 CC of DI water. Stir thoroughly, add 24 drops of 37% NH_4OH and stir thoroughly again. Do the above preparation in a dark room and avoid direct illumination of the $AgNO_3$ solution.

[2] Add 300 mg of NaOH into the solution in [1] and stir thoroughly. Do the above preparation in a dark room and avoid direct illumination of the $AgNO_3$ solution.

Part B of the solution is prepared as follows:

Part B:

[1] Put 60 mg of Sparkleen in a beaker and add 100 CC of DI water. Stir thoroughly.

[2] Put 860 mg of sorbital in a beaker and then add 30 CC of DI water. Stir thoroughly. Add 3 mg of Sparkleen in the beaker and stir thoroughly.
After the cleaning, the silver electroless deposition may be carried out using the procedure described before.

To improve further the quality of waveguides or waveguide components, a second layer of metal may be deposited by electrodeposition after the first metal electroless deposition. The electrodeposition may be carried out by conventional methods employed to deposit Ag or Cu. In this case, the thickness of the first metal layer may be as small as 0.1 micrometer. This thickness is sufficient to serve as the conducting electrode during the electrodeposition for the second metal layer.

Similarly, a diplexer waveguide with a couple of copper foils sandwiched between two waveguide members may be fabricated. The copper foils may be fabricated by patterning to form a predetermined shape. The copper foils are installed inside the waveguide members after the metal layer deposition.

Yet another embodiment of the invention is the fabrication of microwave waveguides and waveguide components utilizing conducting thermal plastics. Using the conductive plastics to fabricate microwave members, metal layers may be deposited by electrodeposition rather than by electroless deposition. This is because the time for electrodeposition to obtain metal layers with a given thickness is generally less than that required for the electroless deposition process. Such conductive plastics are available commercially, for instance from RTP Company, Winona, MN, USA. Using these materials, conductive plastic members for waveguide and waveguide components may be formed by molding. The structures of the conductive members may be similar to those described in Figs. 1, 3 and 4. Since the electrical resistivity of these plastics is not low enough for low loss microwave applications, a layer of metals is needed. The metal layer is deposited by conventional electrodeposition processes. The metals used may be either Ag or Cu. Furthermore, multilayer metal films may be deposited to improve the adhesion. In such applications, a layer of metal with good adhesion to the plastics is first deposited. This is followed by the electrodeposition of either Ag or Cu. Since the electroless deposition process is not required in fabricating the microwave waveguiudes or waveguide components, the additional advantage of the method using molded conductive plastics is thus clear.

The foregoing description is illustrative of the principles of the present invention. Numerous extensions and modifications thereof would be apparent to the person skilled in the art. Therefore, all such extensions and modifications are to be considered to be within the scope and spirit of the present invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for manufacturing microwave waveguides suitable for operation at frequencies above 20 GHz comprising;

-- forming a first component and a second component by the molding of thermoplastic materials, said first component containing at least one surface for connecting to sources, at least one connecting surface for connecting to loads, at least one cavity for propagating of microwaves and at least one female slot for alignment and assembly, said second component containing at least one connecting surface for connecting to sources, at least one surface for connecting to loads, at least one cavity and at least one male slot for alignment and assembly, each of the cavities in said first component coinciding with a cavity in said second component and each female slot in said first component coinciding with a male slot in said second component,

-- coating at least one first layer of metals on said connecting surface and inner walls of cavities of said first component and on said connecting surface and inner walls of cavities of said second component,

-- rinsing in clean water and then drying said first component and said second component,

-- assembling said first component and said second component to form a waveguide structure.

2. A method for manufacturing microwave waveguides as defined in Claim 1 further comprising a step of heat treating said first component and said second component to enhance adhesion of said metal layer.

3. A method for manufacturing microwave waveguides as defined in Claim 1 wherein said metals are selected from a group consisting of Cr, Cu and Ag.

4. A method for manufacturing microwave waveguides as defined in Claim 1 further comprising a step of depositing a second layer of metals by electrodeposition, said metals in second layer being selected from a group consisting of Cu and Ag.

5. A method for manufacturing microwave waveguides as defined in Claim 1 further comprising a step of controlling the radius of curvature between adjacent surfaces in said cavity in order to improve coverage of said first layer of metals.

6. A method for manufacturing microwave waveguide components for operation at frequencies above 20 GHz comprising;

-- forming a first component and a second component by the molding of thermoplastic materials, said first component containing at least one surface for connecting to sources, at least one connecting surface for connecting to loads, at least one recess slot to accommodate elements for the conditioning of microwaves, at least one cavity for the propagating of microwaves and at least one female slot for alignment and assembly, said second component containing at least one connecting surface for connecting to sources, at least one surface for connecting to loads, at least one recess slot to accommodate said elements for the conditioning of microwaves, at least one cavity and at least one male slot for alignment and assembly. Each of the recess slots in said first component coincides with one recess slot in said second component, each of cavities in said first component coincides with a cavity in said second

component and each female slot in said first component coincides with a male slot in said second component,

-- coating at least one first layer of metals on said connecting surface and inner walls of cavities of said first component and on said connecting surface and inner walls of cavities of said second component,

-- rinsing thoroughly said first component and said second component with water,

-- drying thoroughly said first component and said second component in air and then heat treating said first component and said second component in vacuum or in an inert atmosphere,

-- positioning said elements for conditioning of microwaves in recess slots,

-- assembling said first component and said second component with said elements to form a waveguide structure for the conditioning of microwaves.

7. A method for manufacturing microwave waveguide components as defined in Claim 6 further comprising a step of heat treating said first component and said second component to enhance adhesion of said metal layer.

8. A method for manufacturing microwave waveguide components as defined in Claim 6 wherein said metals are selected from a group consisting of Cr, Cu and Ag.

9. A method for manufacturing microwave waveguide components as defined in Claim 6 wherein said elements for the conditioning of microwaves are manufactured on a copper-clad substrate.

10. A method for manufacturing microwave waveguide components as defined in Claim 6, further comprising a step of

depositing a second layer of metals by electrodeposition, said metals in said second layer are selected from a group consisting of Cu and Ag.

11. A method for manufacturing microwave waveguides as defined in Claim 6 further comprising a step of controlling the radius of curvature between adjacent surfaces in said cavity in order to improve coverage of said first layer of metals.

12. A method for manufacturing microwave waveguides and waveguide components suitable for operation at frequencies above 20 GHz comprising;

-- forming a first component and a second component by the molding of electrically conductive thermoplastic materials, said first component containing at least one surface for connecting to sources, at least one connecting surface for connecting to loads, at least one cavity for the propagating of microwaves and at least one female slot for alignment and assembly, said second component containing at least one connecting surface for connecting to sources, at least one surface for connecting to loads, at least one cavity and at least one male slot for alignment and assembly, each of the cavities in said first component coincides with a cavity in said second component and each female slot in said first component coincides with a male slot in said second component,

-- coating at least one layer of metals by an electrodeposition process on said connecting surface and inner walls of cavities of said first component and on said connecting surface and inner walls of cavities of said second component,

-- rinsing in clean water and then drying said first component and said second component,

-- assembling said first component and said second component to form a waveguide structure.

13. A method for manufacturing microwave waveguides as defined in Claim 12 further comprising a step of heat treating said first component and said second component to enhance adhesion of said metal layer.

14. A method for manufacturing microwave waveguides as defined in Claim 12 wherein said metals are selected from a group consisting of Cr, Cu and Ag.

15. A method for manufacturing microwave waveguides and waveguide components as defined in Claim 12 further comprising a step of forming at least one recess slot in said first component and at least one recess slot in said second component, to accommodate elements for the conditioning of microwaves.

16. A method for manufacturing microwave waveguides as defined in Claim 12 further comprising a step of controlling the radius of curvature between adjacent surfaces in said cavity in order to improve coverage of said layer of metals.

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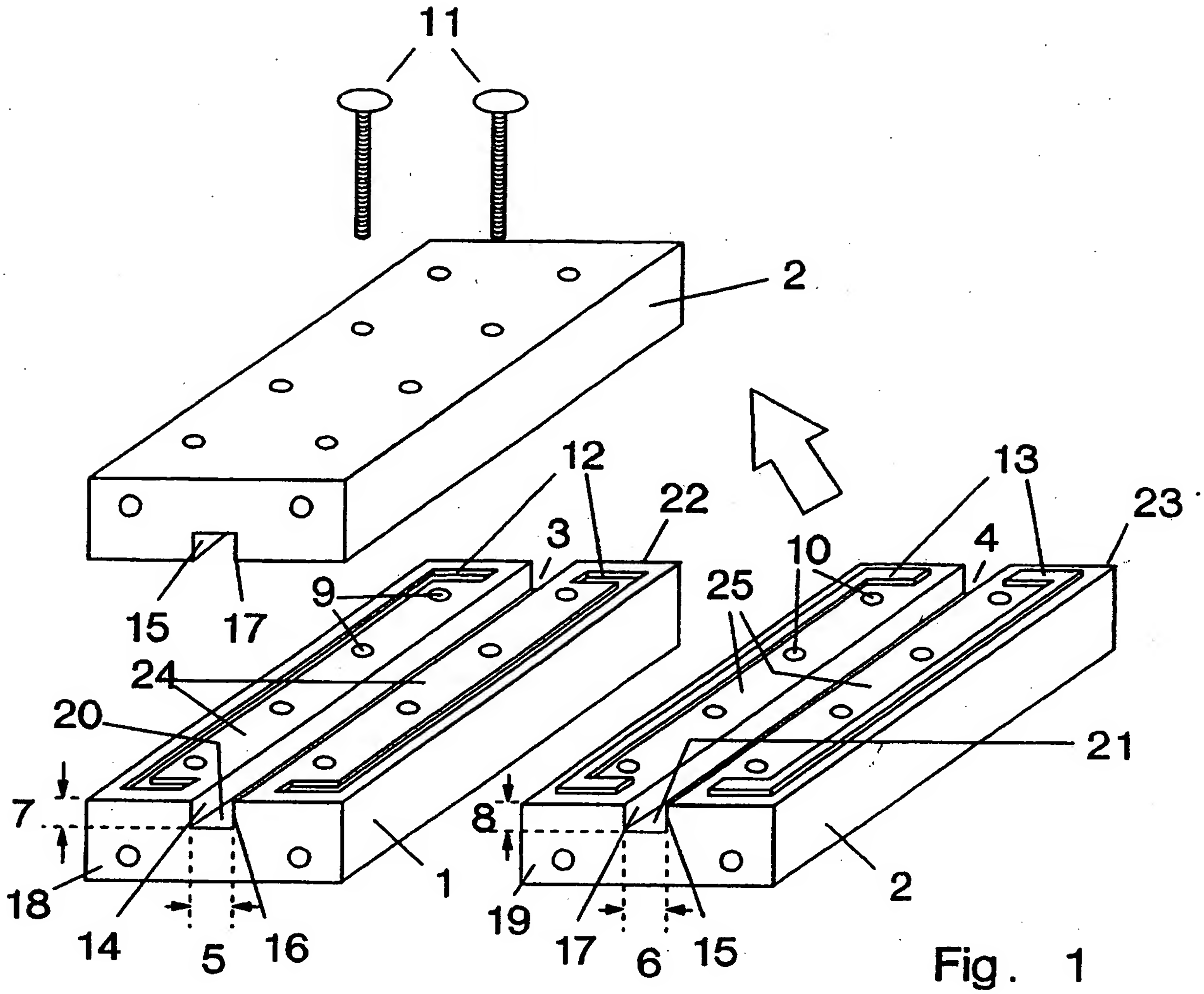

Fig. 1

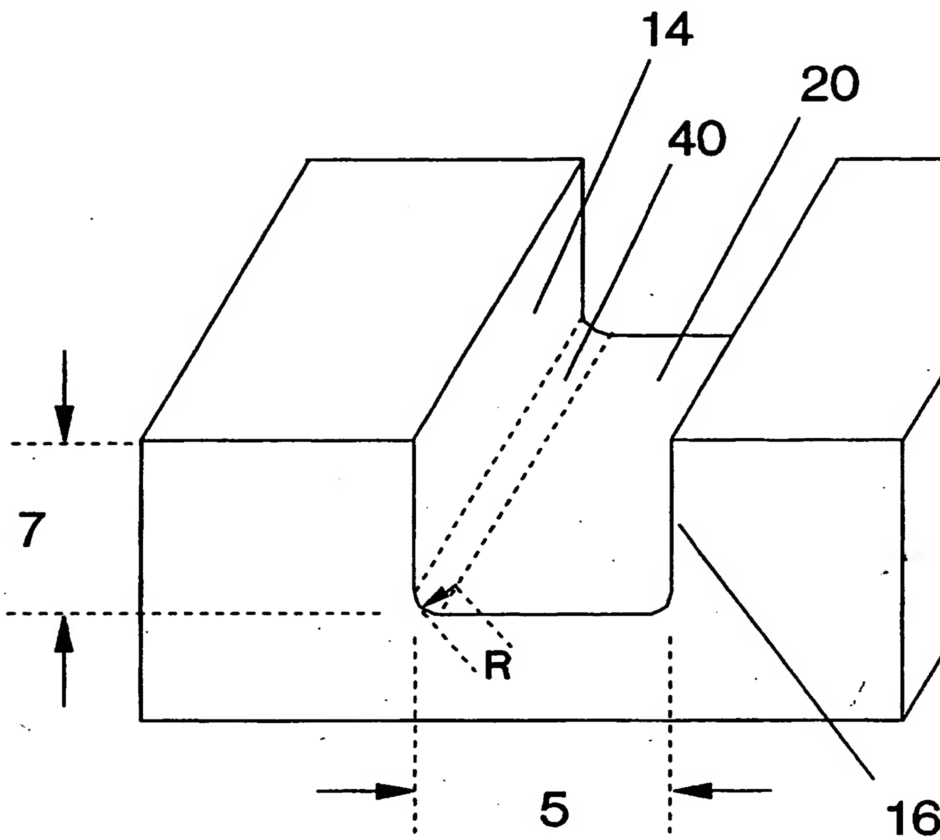

Fig. 2

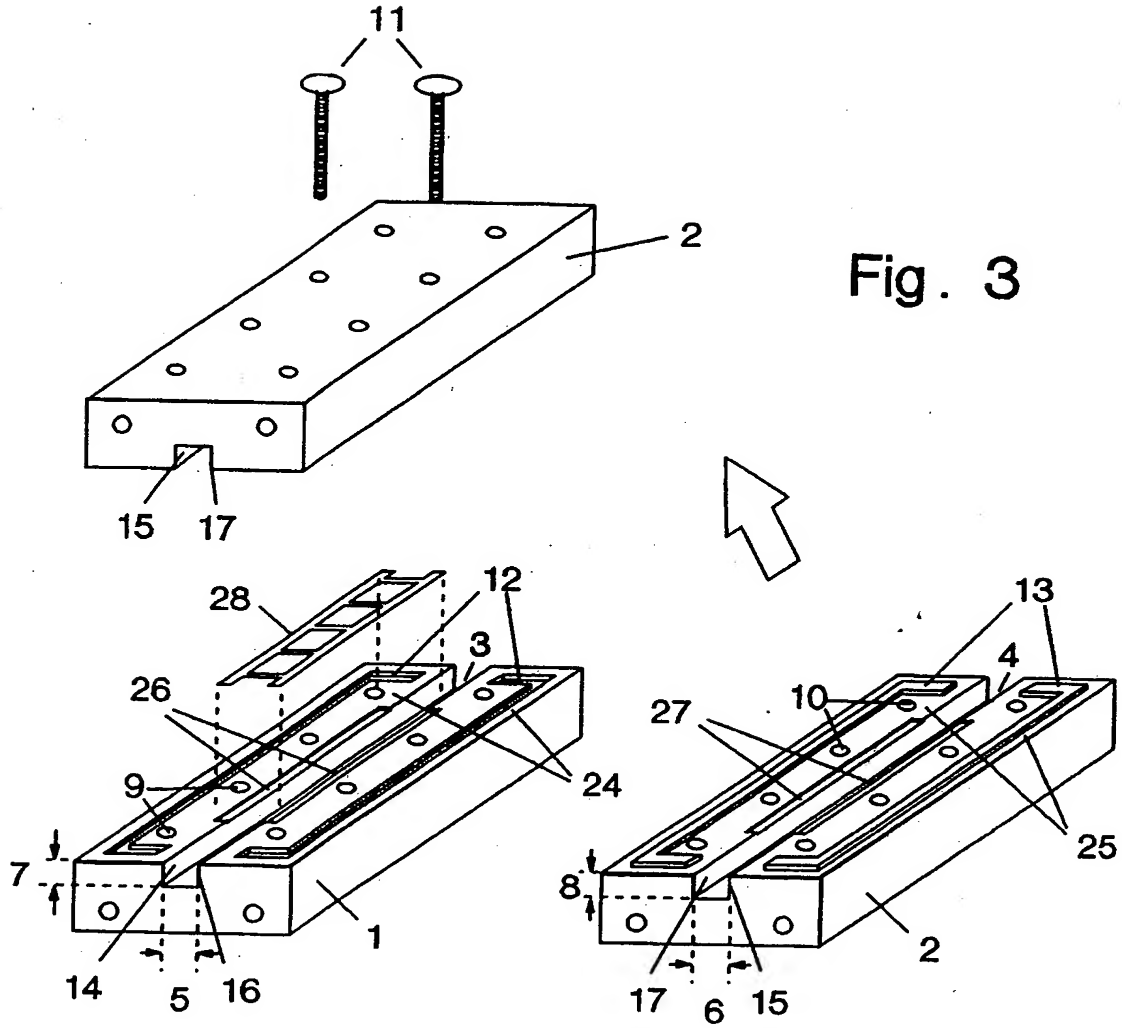

Fig. 3

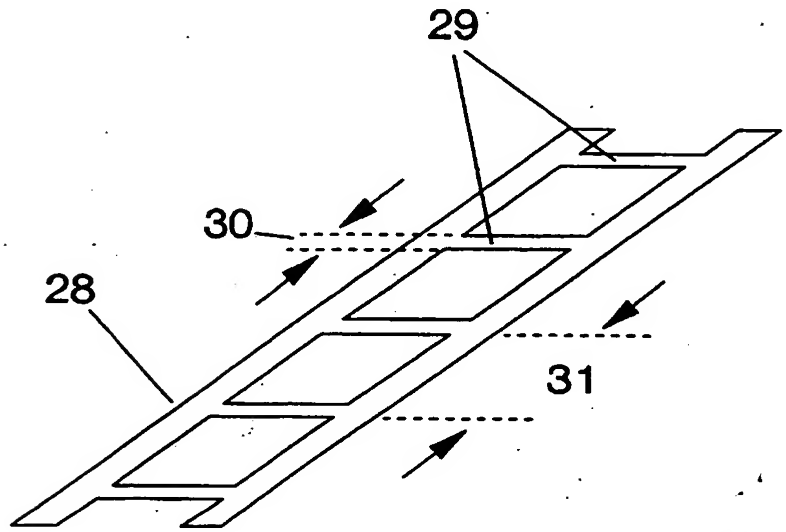

Fig. 4

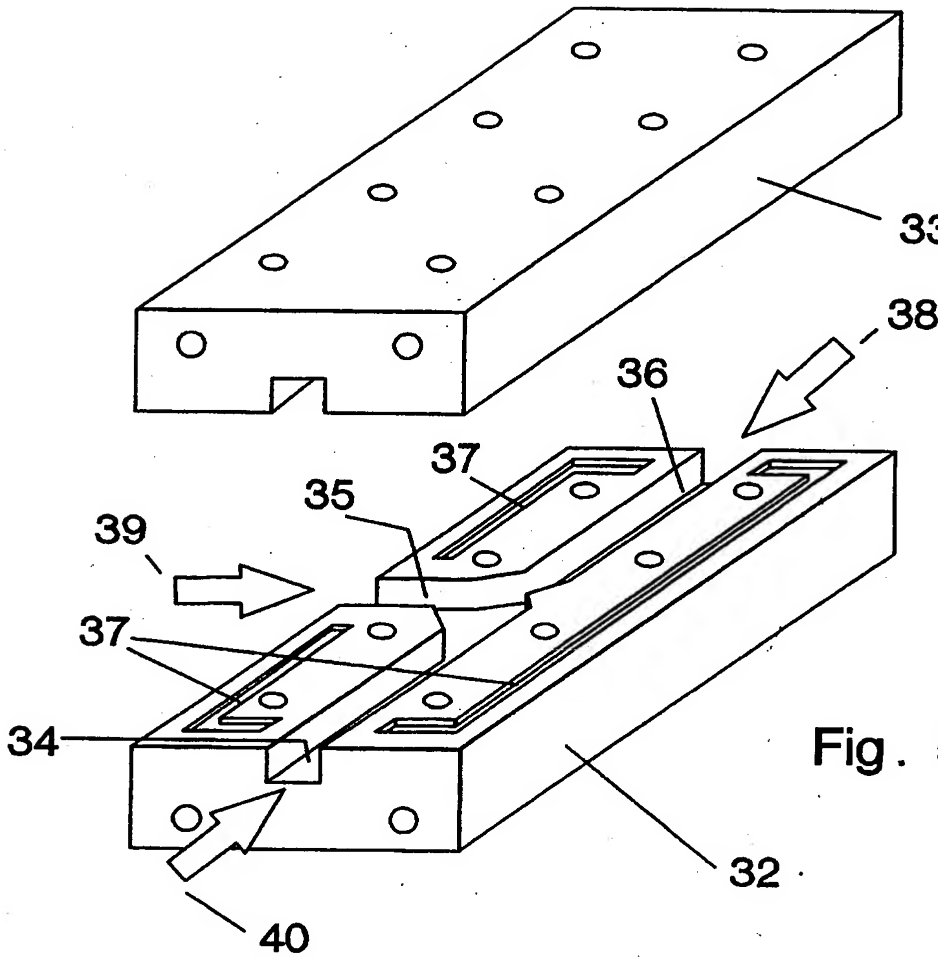

Fig. 5